# Model based formation of Advanced Tokamak discharges

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Advanced tokamak scenarios use an increased bootstrap current ($j_{bs} \propto q\nabla p$) to reduce the reliance of plasma discharges on ohmic current. This is achieved by using external actuators to drive current off-axis, thereby increasing the safety factor $q$ through redistribution of the plasma current. Applying them during the current ramp-up (early-heating) allows for an optimal entry into a desired $q$-profile, avoiding an intermittent drop, which would be present if the plasma were allowed to reach a stationary state first (late-heating). This is of interest for present devices due to short pulses and important for a reactor due to its long current diffusion time.

Due to the volatility of the plasma in the early phase, developing such a scenario usually costs a lot of discharges. In order to overcome this issue, a model has been developed in the transport code ASTRA to simulate such a scenario, using the actuator setup and density as inputs. The core transport is based on Gyro-Bohm, including a simplified ITG and TEM mode contribution, allowing the system to achieve a run time of only a few minutes for a full discharge. Edge transport via a scaling law and the L-H transition based on the heating power at the separatrix are included. The free parameters have been determined by a set of similar reference pulses. These parameters are consistent for comparable plasmas. With this setup it is possible to quickly test various changes to a reference discharge, allowing for a large part of scenario development to be done through modelling only.

A new early-heating scenario for AUG, operating at $q_{95} \sim 5.2$ and $\beta_N \sim 3$, was developed using the model, showing its viability to be used as a tool for scenario design. Multiple different scenarios at different plasma currents and $\beta_N$ for both co- and counter-current ECCD operation were tested and show good agreement with experimental results.

A counter-ECCD scenario with a more DEMO-relevant $q_{95}$ of $\sim 4.1$ has been investigated. Using the model, a redesign of the actuator setup required for technical reasons was done successfully. Further, in order to improve magnetohydrodynamic stability by changing the time evolution of $q$, an optimizer built around the RAPTOR fast core transport solver was used to propose changes to the actuators for this scenario. Those were verified in the ASTRA-model, before running them on AUG. A considerable improvement in confinement was achieved.

Using this framework, first post-discharge comparisons with JET data show good agreement, indicating, that the model can be generalized to different machines without significant changes. Using the model to help with scenario development is planned, results will be presented.